Onsala Space Observatory – IVS Network Station Activities During 2021–2022

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Abstract During 2021 and 2022 we participated in a total of 81 IVS 24-hour legacy S/X sessions with the Onsala 20-m telescope. We observed in a total of 73 VGOS 24-hour sessions with one or both of the Onsala twin telescopes (OTT) in 2021 and 2022. In total we observed 114 VGOS one-hour Intensive sessions during 2021 and 2022, the majority together with the partner station Ishioka in Japan, but also five with Kokee Park. More than 50% of these sessions involved both Onsala twin telescopes. We also performed 22 local interferometry measurements at Onsala during 2021 and 2022 for measuring the local ties between our telescopes that are used for geodetic VLBI. In 2021 we also performed 91 short (20-minute) flux-monitoring sessions with the OTT as a standalone instrument.

1 General Information

The Onsala Space Observatory is the national facility for radio astronomy in Sweden with the mission to support high-quality research in radio astronomy and geosciences. The geoscience instrumentation at Onsala includes three antennas used for geodetic VLBI, several GNSS installations, a superconducting gravimeter, a platform for visiting absolute gravimeters, several microwave radiometers for atmospheric measurements, both GNSS-based and conventional tide gauge sensors, and a seismometer. The observatory can thus be regarded as a fundamental geodetic station. Since 2021 the observatory has been receiving financial support for geoscience operations kindly provided by Lantmäteriet—the Swedish mapping, cadastral, and land registration authority. The staff members associated with the IVS Network Station at Onsala are listed in Table 1.

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IVS 2021+2022 Biennial Report

2 Legacy S/X VLBI Observations

In total, the 20-m radio telescope (On) participated in 42 of the originally planned 46 legacy S/X sessions in 2021. All sessions were recorded with the DBBC2/Flexbuff system, and the data were e-transferred for correlation. The four planned IVS sessions in 2021 that could not be observed due to a strange shaking behavior of the 20-m radio telescope were R11014, R11015, RV149, and T2148. The first three hours of RV150 were lost due to an operator error.

In 2022, the 20-m radio telescope (On) participated in 39 out of the originally planned 47 legacy S/X sessions. The cancellation of eight originally planned sessions was due to the co-observing rules introduced after the Russian invasion war against Ukraine.

3 VGOS 24-hour Observations

In 2021 Onsala participated in 28 IVS 24-hour VGOS sessions. Three sessions in 2021 were observed with only one of the OTT (Onsala twin telescopes), i.e., VO1021 (Ow: compressor problems), VO1133 (Oe: no recording disk space left), and VO1259 (Oe: DBBC3

Table 1 Staff members associated with the IVS Network Station at Onsala in 2021–2022. All e-mail addresses have the ending @chalmers.se, and the complete telephone numbers start with the prefix +46-31-772.

Function	Name	e-mail	telephone
Responsible P.I.s for geodetic VLBI observations	Rüdiger Haas	rudiger.haas	5530
	Eskil Varenius	eskil.varenius	5558
	Karine Le Bail	karine.lebail	5556
Ph.D. students involved in geodetic VLBI	Periklis-Konstantinos Diamantidis	periklis.diamantidis	5575
	Rebekka Handirk (since 2020-09-15)	rebekka.handirk	5575
Responsible for the VLBI Field System	Michael Lindqvist	michael.lindqvist	5508
	Rüdiger Haas	rudiger.haas	5530
	Eskil Varenius	eskil.varenius	5558
Responsible for the VLBI equipment	Magnus Dahlgren	magnus.dahlgren	5594
	Lars Pettersson	lars.pettersson	5568
Responsible for the VLBI operators and data recording and transfer equipment	Roger Hammargren	roger.hammargren	5551
	Simon Casey	simon.casey	5529
	Eskil Varenius	eskil.varenius	5558
Telescope scientist	Henrik Olofsson	henrik.olofsson	5564
Software engineer	Mikael Lerner	mikael.lerner	5581
Responsible for gravimetry	Maxime Mouyen	maxime.mouyen	5549
Responsible for tide gauge and radiometry	Gunnar Elgered	gunnar.elgered	5565
Responsible for aeronomy and radiometry	Peter Forkman	peter.forkman	5577
Observatory director	John Conway	john.conway	5503

phase coherence loss). All other 24-hour VGOS sessions in 2021 were observed with both OTT.

Onsala participated in 44 IVS 24-hour VGOS sessions in 2022. Two of the originally planned 46 sessions were cancelled due to a general change of the IVS VO cadence in late 2022. Out of the 44 sessions, 24 were observed with both OTT. Ow did not participate in 14 sessions between March and May 2022 because its DBBC3 was in Bonn for upgrade. Oe did not participate in VR2203 due to paint work. Oe did not participate in VO2153 due to paint work and lack of recording disk space. Oe did not participate in VO2160 due to unresolved interlock problems and did not participate in VO2181 due to a problem with the AC unit in the azimuth cabin. Oe did not participate in VO2293 due to lack of recording disk space. Ow did not participate in VR2206 due to lack of recording disk space and cryoservice. Furthermore, Ow stopped observing early during VO2132 due to DBBC3 problems, and Oe lost about one hour of observations during VO2363 due to interlock problems.

Both OTT participated in the European VGOS Research and Development session ER2201 in 2022.

4 VGOS One-hour Intensive Observations

Between January and early March 2021 Onsala observed 25 VGOS-Intensive one-hour sessions for UT1-UTC determination together with the partner station Ishioka in Japan. These sessions were observed on Saturdays and Sundays and involved both OTT. The raw data from Ishioka were e-transferred to Onsala for correlation and creation of the vgosDbs.

Between mid March and early October 2022, Onsala observed 84 VGOS-Intensive one-hour sessions for UT1-UTC determination together with the partner station Ishioka in Japan. These sessions were observed on Saturdays and Sundays, and 36 of the sessions involved both OTT. The remaining 48 sessions were observed with either Oe or Ow due to various reasons. For example, Ow did not participate from March through early May because its DBBC3 was in Bonn for upgrade. In late May Oe did not participate due to ongoing paint work on the telescope. In early June Oe did not participate due to interlock problems. In early July Oe did not participate due to a problem with the AC unit in the azimuth cabin. The raw data from Onsala were e-transferred to GSI in Tsukuba for correlation and creation of vgosDbs.

In December 2022, Oe observed five VGOS-INT-A (V2) sessions for UT1-UTC determination. A sixth planned session was cancelled due to a power outage at Kokee Park. The observed data were sent for correlation to the USNO Washington correlator, and UT1-UTC results were determined within about 24 hours.

5 Local Interferometry Observations

In 2021 and 2022 we performed 13 and nine, respectively, local interferometric 24-hour sessions involving the Onsala 20-m telescope and the OTT. These so-called ONTIE-sessions use a special X-band frequency setup that is adjusted for the local RFI environment at Onsala. The sessions were planned, scheduled, observed, correlated, fringe-fitted, and analyzed at Onsala. The majority of the sessions were 24-hour long during which typically more than 1,000 scans were observed. One of the 2022 sessions failed and could not be used to create a vgosDb. Some details are provided in [1, 2].

In 2021 we also performed 91 short (20-minute) flux-monitoring sessions with the OTT as a standalone instrument. These flux-monitoring (FM) sessions were scheduled, correlated, and analyzed at Onsala [3].

6 Monitoring Activities

We continued with monitoring activities:

Pressure sensors. In addition to the primary barometer at the Onsala site, the measurements of which are archived in the observational log files, several others are operated as a back-up resource. During 2021–2022, levelling was carried out in order to determine the height of each sensor. Analysis of these data together with differences of the observed pressure is ongoing in order to evaluate their accuracy at an absolute level. Because the pressure at sea level roughly decreases by 0.1 hPa/m, and the zenith hydrostatic delay has a sensitivity of $\approx$2.3 mm/hPa, the required accuracy of the levelling is rather modest, say at the centimeter level.

Vertical changes of the 20-m telescope tower. We continue to monitor the vertical changes of the telescope tower using the invar rod system at the 20-m telescope. The measurements are available at `http://wx.oso.chalmers.se/pisa/`.

The local geodetic network. During the summer of 2022 a re-survey of the local geodetic network at the Onsala Space Observatory was carried out as part of a student project in collaboration with colleagues from the Frankfurt University of Applied Sciences, Germany. This included both measurements with levelling instruments as well as total stations. The vertical positions of the various meteorological stations at the observatory were determined as well.

Superconducting gravimetry. The superconducting gravimeter (SG) operated continuously during 2021 and 2022 and produced a highly accurate record of gravity variations. As part of the regular maintenance, the cold head was changed on September 30, 2021. A higher noise background was observed at low frequency (around 0.02 Hz). The problem was eventually found to be a physical contact between the coldhead and the neck of the SG's dewar. Uplifting the coldhead by a few mm solved the issue. The next coldhead swap was done on December 6, 2022. In October and December 2022 the SG had some power issues that tended to trigger spikes in the data. This was due to an excessive power load applied to the continuous self-levelling system of the device. Under the guidance of the manufacturer GWR, we adjusted the tilts of the gravimeter to reduce that load, and the spikes stopped occurring after that. Tide solutions were prepared on a weekly basis, and results are available on the SG homepage (`http://holt.oso.chalmers.se/hgs/SCG/toe/toe.html`).

Absolute gravimetry. Lantmäteriet visited the observatory twice with their FG5 instrument in 2021 and 2022. In 2022 we also hosted the NKG absolute gravimeter intercomparison at Onsala. Comparing absolute gravimeters is necessary to assess the accuracy of these instruments. The comparison was arranged as an additional comparison according to the CCM-IAG strategy for Metrology in absolute gravimetry. To guarantee traceability to the SI, its results will be linked to the International and European key comparisons (CCM.G-K2.2017 and EURAMET.M.G-K3) through joint participants. The intercomparison campaign was held during seven weeks between May and July in 2022. In total 15 different instruments participated, of which five were from the Nordic countries. Both ballistic (FG5X, FG5, and A10) and quantum (AQG) absolute gravimeters participated in the intercomparison. The SG, located at Onsala, continuously kept track of local gravity variations, especially due to hydrological effects. It allows proper comparison of all absolute gravity measurements across the seven week duration of the intercomparison campaign.

Seismological observations. The seismometer owned by Uppsala University and the Swedish National Seismic Network (SNSN) was operated throughout the two-year period.

Water vapor radiometry. The water vapor radiometers (WVR) at Onsala, Astrid, and Konrad, are designed to measure the sky brightness temperatures at 21 GHz and 31 GHz from which the radio wave propagation delay in the atmosphere can be inferred. As reported earlier, Astrid failed during a thunderstorm in 2019, and it is unclear whether it will be operational again. If so, it will be observing towards a specific position on the sky, i.e., it will not be steerable. During 2021 Konrad was operating from April 1, 2021 to September 30, 2021. Occasionally occurring gain jumps were identified to be caused by a slightly broken waveguide which was repaired while the WVR was in the electronic lab during the first three months of 2021. In spite of the gain jumps, horizontal gradients of high quality could be estimated and used to assess four different GNSS stations at the Onsala site [4]. Starting in October 2021, maintenance was carried out until January 12, 2022. An unstable power supply was replaced as well as the more than ten-year old control and data acquisition computer. During 2022 Konrad was operating from January 12 to the end of the year. There were just a few data gaps due to computer failure, internet failure, and human interference, in total a few days. The largest loss of data was due to rain, or very heavy clouds, in the observed volume of air, which causes the retrieval algorithm to suffer from large uncertainties. In 2022 useful data were acquired during $\approx$82% of the year. A new radiometer was ordered in 2022 and is expected to be delivered in the spring of 2023.

Tide gauge measurements. The official tide gauge station at Onsala is a part of the national observational network for sea level operated by the Swedish Meteorological and Hydrological Institute (SMHI). The data are available via SMHI web pages (open access). It has been in continuous operation since the summer of 2015. The Onsala tide gauge station ran uninterrupted for the entire year of 2021, excluding the yearly cleaning of the well and a sensor calibration campaign, when we artificially controlled the sea level in the well, causing a data gap of less than six hours on July 6, 2021. A second data gap of two hours occurred on August 27, 2021 when new nozzles for the pneumatic sensors were installed. During 2022 the Onsala tide gauge station ran uninterrupted for the entire year, excluding the yearly cleaning of the well, causing a data gap of less than three hours on August 10, 2022.

Onsala's other GNSS-based tide gauge was also operational continuously during 2021 and 2022, providing observations with a sampling rate of 1 Hz. The data records are nearly complete, and the data are stored in Receiver Independent Exchange Format (RINEX) format including multi-GNSS (i.e. GPS, GLONASS, Galileo, and Beidou) code- and carrierphase observations as well as signal-to-noise ratio (SNR) measurements.

7 Future Plans

In the coming two years we plan to

- participate in about 50 IVS legacy S/X sessions per year with the 20-m telescope,
- participate in as many VGOS sessions as possible,
- continue the local interferometric measurements with the Onsala telescope cluster on a regular basis,
- run an Onsala flux-monitoring program,
- continue the work concerning local tie vectors between the telescopes' reference points using classical geodetic observations as well as with gimbal-mounted GNSS-antennas on the telescopes, and
- continue the monitoring activities.

References

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